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RELATION OF KERNEL TEXTURE TO THE PHYSICAL CHARACTERISTICS, MILLING AND BAKING QUALITIES, AND CHEMICAL COMPOSITION OF WHEAT

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INTRODUCTION

Wheats of certain classes containing a high percentage of hard and vitreous kernels usually command a premium over the price paid for the yellower or more starchy appearing wheats of the same class. The reason is that the hard vitreous kernels are more glutenous and are generally believed to have superior bread-making qualities. This belief has existed in the minds of the grain trade for many years, and because of it when the official United States grain standards were promulgated, the percentage of hard and vitreous kernels present was taken as the basis for establishing subclasses for the hard red spring, hard red winter, durum, and white wheat classes.

In the official grade requirements for the hard red spring and hard red winter wheat subclasses, these kernels are referred to as "dark, hard, and vitreous"; for the durum wheat subclasses as "hard and vitreous kernels of amber color"; and for the white wheat subclasses as "hard (not soft and chalky)".

SOURCE AND DESCRIPTION OF SAMPLES USED

To establish definitely whether a relationship exists between kernel texture and milling and baking quality, the following special studies on the hard red spring, hard red winter, and durum classes were made.

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With the aid of certain of the Federal grain supervision offices of the Bureau of Agricultural Economics and the Office of Cereal Investigations of the Bureau of Plant Industry, three special samples each of hard red winter and hard red spring and two of durum wheat were obtained and from a portion of each of these there were separated, by hand picking, a sufficient quantity for milling, baking, and chemical tests of kernels of the three following types of texture: (1) Dark, hard, and vitreous, or amber; (2) spotted or mottled; and (3) yellow or starchy. Considerable care was taken to make these separations as distinct and consistent as possible; that is, the kernels selected as dark, hard, and vitreous, or as hard and vitreous and of amber color were practically 100 per cent free from starchy specks or spots. For the sake of convenience this type of kernel texture hereafter will be referred to as "dark." The yellow or starchy kernels varied from seven-eighths starchy to all starchy in appearance. The spotted or mottled kernels included the in-between range of starchiness, from a mere speck up to seven-eighths, and for that reason varied more widely in appearance than did the kernels of the other two separations.

The separations of kernels of dark type of texture made in connection with this experiment corresponded with the separations which are made in the grading or inspection of wheat for marketing purposes, except that the latter usually include the slightly mottled kernels.

Three of the samples selected represented commercially-grown wheat, and five were true varietal wheats grown at agricultural experiment stations. In procuring the commercial samples, care was taken to insure against their being mixtures of wheats from different sections of the country. The true varietal samples were selected in order that, on at least a portion of the experiment, there would be positive assurance that any differences shown in results would not be due to differences in variety, climate, soil, or cultural conditions. Furthermore, for the sake of convenience in separating, each selection was of bright clean wheat containing approximately equal proportions of these three different textures of kernels. There was one exception in the case of the hard red winter wheat sample No. 7489 from Lincoln, Nebr., which was slightly bleached from weathering.

The separating of these kernels by hand in quantities sufficient for the tests involved a tremendous amount of tedious work. In separating the kernels into these three texture groups all foreign material and broken and damaged kernels were discarded. Before milling the portion representing the original sample the foreign material present was removed but not the broken and damaged kernels.

The hard red spring wheat samples, M. I. Lab. Nos. 7006 and 7276, were obtained in Oregon and No. 7066 was obtained in Minnesota. Samples Nos. 7006 and 7066 represented commercially grown wheat and No. 7276 represented the Marquis variety grown on a single experimental plot at the agricultural experiment station, Corvallis, Oreg.

The hard red winter wheat samples bear the M. I. Lab. Nos. 7005, 7154, and 7489. Sample No. 7005 was a commercially grown wheat from St. Marys, Kans. The samples numbered 7154 and 7489 were both of the Kharkof variety. The former sample was

grown at the United States Plant Introduction Station, Chico, Calif., and the latter at the agricultural experiment station, Lincoln, Nebr.

The two durum wheat samples tested bear the M. I. Lab. Nos. 7401 and 7402. These both represent true varietal wheats grown at the agricultural experiment station, St. Paul, Minn. Sample No. 7401 was of the Arnautka variety and 7402 of the Kubanka variety.

In addition to the results given in tabular form, graphs are presented for some of the more important factors discussed, that the results may be more readily compared and that the extent of the differences may be more apparent.

PHYSICAL CHARACTERISTICS OF KERNELS OF DIFFERENT TEXTURES

In Table 1 data are presented that show the test weight per bushel of the cleaned wheat in each separation before scouring, the test weight after scouring, the weight per thousand kernels, and the specific gravity.

TABLE 1.—*Data pertaining to the physical characteristics of kernels of the different types of texture*

Laboratory No. of sample	Type of kernel texture	Test weight per bushel		Weight per 1,000 kernels	Specific gravity
		Before scouring	After scouring		
	HARD RED SPRING WHEAT SAMPLES				
		Pounds	*Pounds*	*Grams*	
7006	Dark	59.4	60.0	24.7	1.3816
	Mottled	62.2	62.8	30.5	1.3801
	Starchy	60.9	61.9	29.3	1.3538
7066	Dark	62.3	62.8	28.8	1.3879
	Mottled	62.3	63.0	27.7	1.3835
	Starchy	60.1	60.6	27.4	1.3226
7276	Dark	63.2	64.2	29.7	1.4023
	Mottled	63.3	64.1	33.9	1.3722
	Starchy	62.0	63.1	32.1	1.3426
	HARD RED WINTER WHEAT SAMPLES				
7005	Dark	61.4	62.9	23.7	1.4163
	Mottled	61.7	63.2	25.0	1.4094
	Starchy	60.7	62.0	25.1	1.3533
7154	Dark	62.1	63.1	29.1	1.4135
	Mottled	62.3	63.3	31.8	1.3856
	Starchy	61.2	61.9	32.6	1.3450
7489	Dark	60.6	62.1	26.9	1.3850
	Mottled	58.9	60.1	26.7	1.3343
	DURUM WHEAT SAMPLES				
7401	Dark	63.4	63.1	46.0	1.3977
	Mottled	63.6	63.3	43.7	1.3763
	Starchy	62.3	62.1	39.1	1.3371
7402	Dark	63.5	63.1	41.5	1.3980
	Mottled	63.5	63.2	42.0	1.3845
	Starchy	62.4	62.1	37.1	1.3430

TEST WEIGHT PER BUSHEL

A study of the test weights per bushel in Table 1 and in the graphs in Figure 1, shows that, of the three types of kernel textures, the mottled kernels were generally highest and the starchy kernels lowest

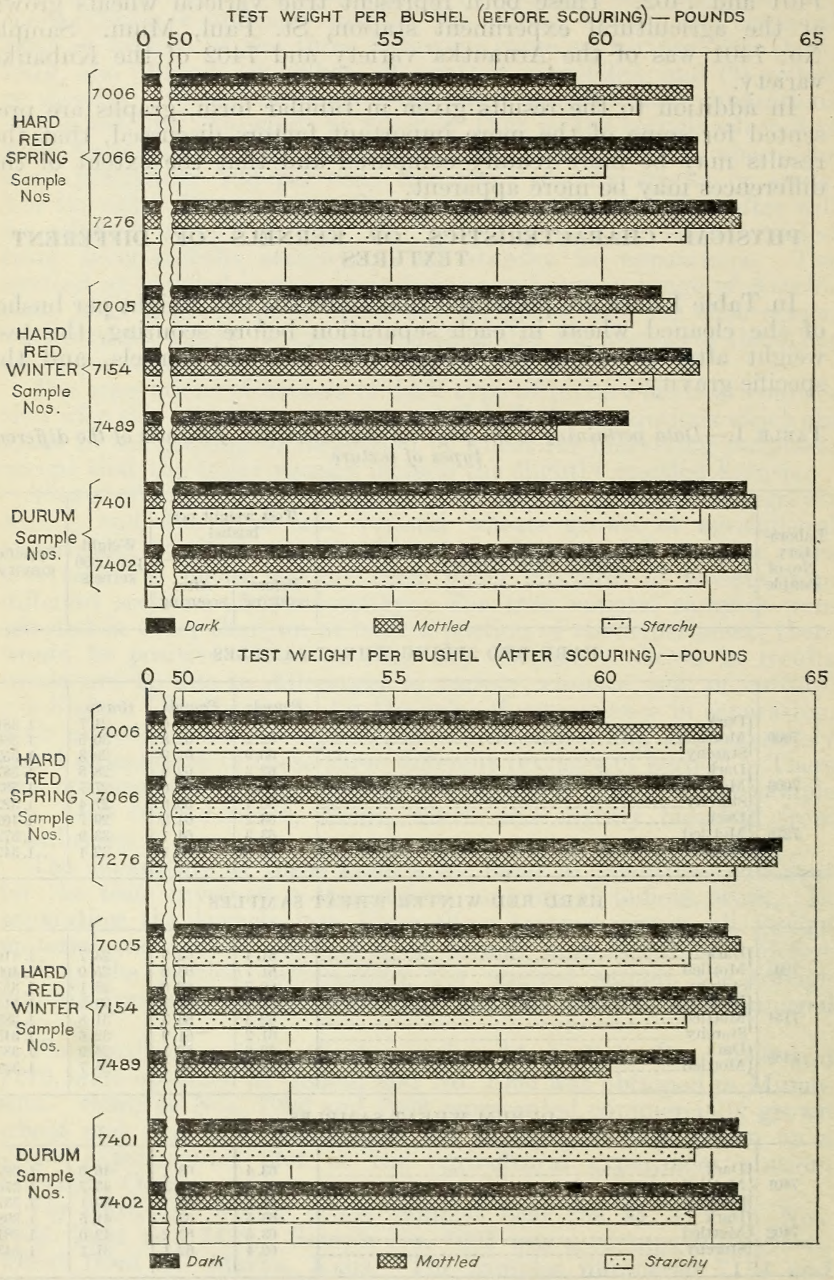

FIG. 1.—Comparison of the test weight per bushel of the separations of dark, mottled, and starchy kernels of wheat

in test weight per bushel both before and after scouring. The differences in test weight between kernel textures were comparatively small. The kernels of dark texture averaged 62.2, the mottled 62.7, and the starchy 61.4 pounds in test weight before scouring and 62.7, 63.3, and 62 pounds, respectively, in test weight after scouring.

Although not of particular importance in connection with kernel texture, it is of interest that scouring had the effect of increasing the test weight of every one of the hard red spring and hard red winter wheat separations, whereas with the durum separations it had just the opposite effect. The reason for this reversal of effect in the case of the durum wheat separations is not known, but a similar tendency has been observed before in connection with tests on other durum samples.

WEIGHT PER 1,000 KERNELS

A considerable spread was shown in weight per 1,000 kernels. The lowest weight was 23.7 grams for the dark kernel separation of the hard red winter wheat sample No. 7005 and the highest weight was 46 grams for the dark separation of the durum sample No. 7401. Considering all the samples no consistent tendency was shown for any type of separation to weigh more than any other type. The only definite fact established by the results was that the weights of the durum separations were in every instance higher than those of the hard red spring and hard red winter wheat samples.

It might be expected that the weight per 1,000 kernels would have a consistent relation to test weight per bushel but this is not the case. For example, in the separations for the hard red winter Kharkof variety sample No. 7154 the starchy textured kernels, although lowest in test weight per bushel both before and after scouring, was highest in weight per 1,000 kernels.

SPECIFIC GRAVITY OF KERNELS

The data presented on specific gravity show a very definite relationship between that factor and kernel texture. In each sample the dark separation was highest in specific gravity and the strachy separation lowest. The mottled separations of four of the samples, however, were higher in specific gravity than were some of the dark separations from other samples.

MILLING YIELDS

In Table 2 the milling results obtained from the various types of kernel texture are given. The products resulting from the milling of these wheats were straight flour, bran, and shorts.

The results given for flour yields were in most cases highest for the dark kernels. This is particularly significant because the dark kernels were not highest in test weight per bushel. In other mill products the starchy kernels usually yielded the greatest percentage of bran and the least percentage of shorts. No consistent differences in bran or shorts yields were noticeable between the dark and mottled kernels. The durum wheat separations consistently yielded the highest percentages of flour and the hard red spring wheat samples yielded the lowest.

In milling gain or loss the greatest gains usually resulted in connection with the dark kernels and in every instance the least gain, or greatest loss as the case may be, occurred with the mottled or starchy kernels. In consideration of the small number of samples tested and of the relatively high experimental error in milling yields, only slight reliance should be placed in the yield tendencies noted here.

TABLE 2.—*Milling results from the different types of kernel texture*

Laboratory No. of sample	Type of kernel texture	Yield of flour	Yield of bran	Yield of shorts	Milling loss (−) or gain (+)
	HARD RED SPRING WHEAT SAMPLES				
		Per cent	*Per cent*	*Per cent*	*Per cent*
7006	Dark	69.4	14.8	16.5	+0.7
	Mottled	68.8	13.7	16.7	−0.8
	Starchy	69.2	16.8	15.2	+1.2
7066	Dark	71.8	15.9	15.0	+2.7
	Mottled	72.9	14.8	14.4	+2.1
	Starchy	70.6	20.4	10.7	+1.7
7276	Dark	70.7	15.4	13.4	−0.5
	Mottled	72.3	15.5	11.5	−0.7
	Starchy	69.5	14.4	15.5	−0.6
	HARD RED WINTER WHEAT SAMPLES				
7005	Dark	73.7	17.7	11.5	+2.9
	Mottled	73.8	12.6	15.3	+1.7
	Starchy	72.6	17.5	11.7	+1.8
7154	Dark	74.3	13.4	15.3	+3.0
	Mottled	72.8	14.8	14.8	+2.4
	Starchy	71.8	16.5	13.9	+2.2
7489	Dark	73.3	15.9	12.9	+2.1
	Mottled	73.0	14.9	13.0	+0.9
	DURUM WHEAT SAMPLES				
7401	Dark	75.4	9.7	15.6	+0.7
	Mottled	75.0	9.5	14.7	−0.8
	Starchy	74.6	12.7	12.9	+0.2
7402	Dark	75.7	13.1	12.6	+1.4
	Mottled	73.5	13.5	14.3	+1.3
	Starchy	74.5	15.9	11.2	+1.6

BAKING RESULTS

Data concerning the baking results are presented in Table 3. Duplicate baking tests were made for each of the separations. The quantity of flour used for each test was 340 grams regardless of the moisture content of the flour. The results here given for loaf volume, water absorption, and weight of loaf, however, are on the uniform basis of 340 grams of flour at 13.5 per cent moisture content.

TABLE 3.—*Baking results from the different types of kernel texture*

Laboratory No. of sample	Type of kernel texture	Water absorption of flour [1]	Volume of loaf [1]	Weight of loaf [1]	Color of bread	Texture of bread
	HARD RED SPRING WHEAT SAMPLES					
		Per cent	*Cubic centimeters*	*Grams*	*Score*	*Score*
7006	Dark	59.6	2,180	496	94.3	90.5
	Mottled	56.7	1,890	493	93.0	91.0
	Starchy	50.7	1,840	471	91.0	87.0
7066	Dark	57.9	2,140	494	95.0	92.3
	Mottled	55.5	2,040	489	94.0	90.0
	Starchy	54.6	2,050	488	94.5	90.3
7276	Dark	59.3	2,050	498	93.5	91.5
	Mottled	57.8	1,930	497	93.5	91.0
	Starchy	55.4	1,910	488	93.0	87.0
	HARD RED WINTER WHEAT SAMPLES					
7005	Dark	58.8	2,160	500	93.0	91.3
	Mottled	58.5	2,020	501	93.8	90.5
	Starchy	57.1	1,910	500	93.0	90.5
7154	Dark	61.6	2,060	508	93.0	90.0
	Mottled	55.2	2,000	496	93.0	88.3
	Starchy	53.8	1,900	487	93.0	87.0
7489	Dark	57.0	2,280	490	94.0	95.5
	Mottled	56.5	2,370	488	93.8	96.0
	DURUM WHEAT SAMPLES					
7401	Dark	60.2	1,850	502	91.5	91.0
	Mottled	55.9	1,860	491	91.5	91.5
	Starchy	53.4	1,940	485	90.8	91.5
7402	Dark	57.8	1,890	491	91.0	90.0
	Mottled	58.3	1,980	493	91.5	90.5
	Starchy	52.4	2,080	474	91.0	92.0

[1] Basis flour (340 grams) at 13.5 per cent moisture content.

WATER ABSORPTION OF FLOUR

In water absorption of flour the dark kernel separations were highest in every instance except in the durum sample No. 7402, and in every instance lowest for the starchy kernel separations. The differences shown in most cases were very marked. For instance, in sample No. 7006 the water absorption for the dark kernels was 59.6 per cent, whereas for the mottled kernels it was 2.9 per cent less and for the starchy kernels 8.9 per cent less. This consistent and marked relationship between kernel texture and water absorption, because of the influence of water absorption upon the number of pounds of bread that can be produced from a given quantity of flour, argues well for the higher baking value of the dark kernel types of wheat. A graphic comparison of the water absorptions of flour for the three different types of kernel textures is given in Figure 2.

VOLUME OF LOAF

In all the hard red spring and in all except one of the hard red winter wheat samples the greatest loaf volumes resulted from the dark-kernel type separations. The exception noted may have resulted in part at least from the fact that this hard red winter sample

had been exposed to wet harvest conditions, thereby slightly bleaching many of the kernels and causing some of them to be separated as mottled or starchy when probably they should have been separated as dark. Furthermore, the same condition which caused this may have had a maturing effect on the kernel or may have started germination to an extent sufficient to improve the baking quality as it is a well-established fact that the admixture of small quantities of slightly germinated wheat with sound wheat noticeably improves the loaf volume. In the two durum samples the best loaf volumes were from the starchy separations. Inasmuch as the durum samples were normal in the matter of condition, it is probable that this is a normal tendency for this class of wheat. In Figure 3 is given a graphic comparison of the loaf volumes for the various separations.

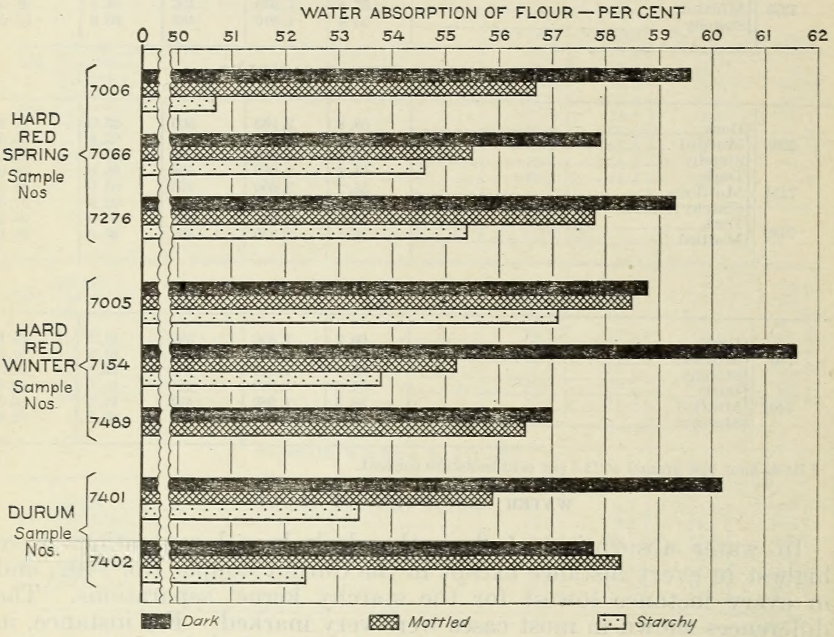

FIG. 2.—Comparison of the water absorption of the flours milled from the separations of dark, mottled, and starchy kernels of wheat

WEIGHT OF LOAF

With but two exceptions the loaves baked from the flour produced from the dark kernels weighed the most, and all except one from the starchy kernels weighed the least. This is in accordance with what should be expected when considered in connection with the water absorptions of these flours which showed a similar relationship to kernel texture.

TEXTURE OF BREAD

As in loaf volume the dark kernel separations of the hard red spring and of the hard red winter wheat samples and the starchy separations of the durum samples showed, except in the instance of wheat No. 7006, the best texture of bread, or in other words, the separations giving the best loaf volumes also gave the best texture of bread.

COLOR OF BREAD

In color of bread the dark kernels were superior in three out of eight samples, tied for first honors with the mottled kernels in three other samples, and were inferior to the mottled kernels in the two remaining samples which indicates only a very slight tendency toward superiority on the part of the dark kernels.

It is interesting to note in connection with the durum wheat separations that, unlike the results obtained for loaf volume and texture of bread, the starchy separations gave the lowest scores instead of the highest. Furthermore, the color of bread for the durum wheat separations was almost the reverse of that of the flour. The starchy separations produced the flour of lightest color, but the

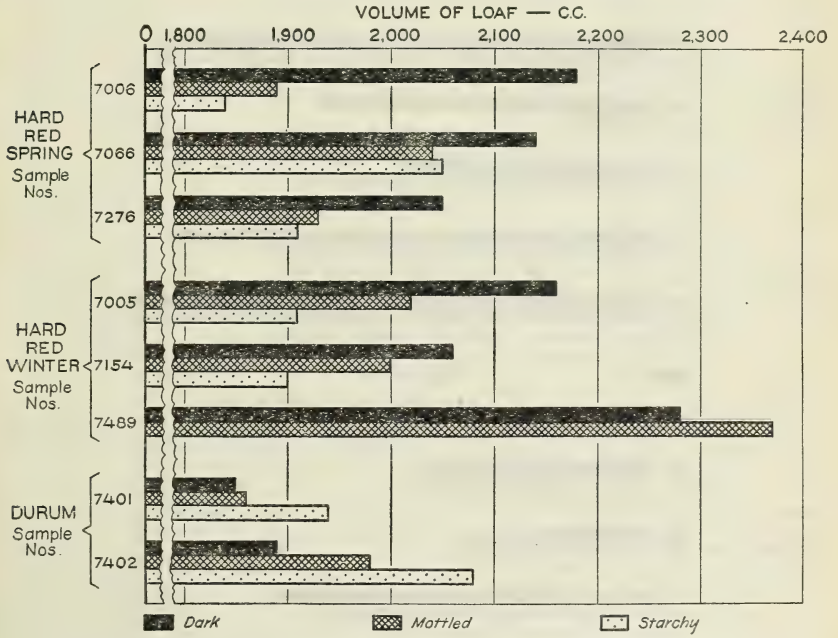

FIG. 3.—Comparison of the loaf volumes of the bread baked from the flours milled from the separations of the dark, mottled, and starchy kernels of wheat

bread baked from this flour was creamier than the bread from the dark separations.

CHEMICAL COMPOSITION OF WHEAT KERNELS OF DIFFERENT TEXTURES

Determinations were made of the chemical composition of wheat kernels of the three types (dark, mottled, and starchy), as well as of the flour milled from these wheats in connection with the milling and baking studies. Unless otherwise noted the methods used were those found in the official and tentative methods of analysis of the Association of Official Agricultural Chemists. These data are given in Table 4. All data are reported on a 13.5 per cent moisture basis.

ASH, CRUDE FIBER, AND FAT CONTENT

It appears from the data presented and from the upper graph in Figure 4 that the starchy kernels of five of the eight samples contained less ash and less fiber than the dark and more vitreous kernels.

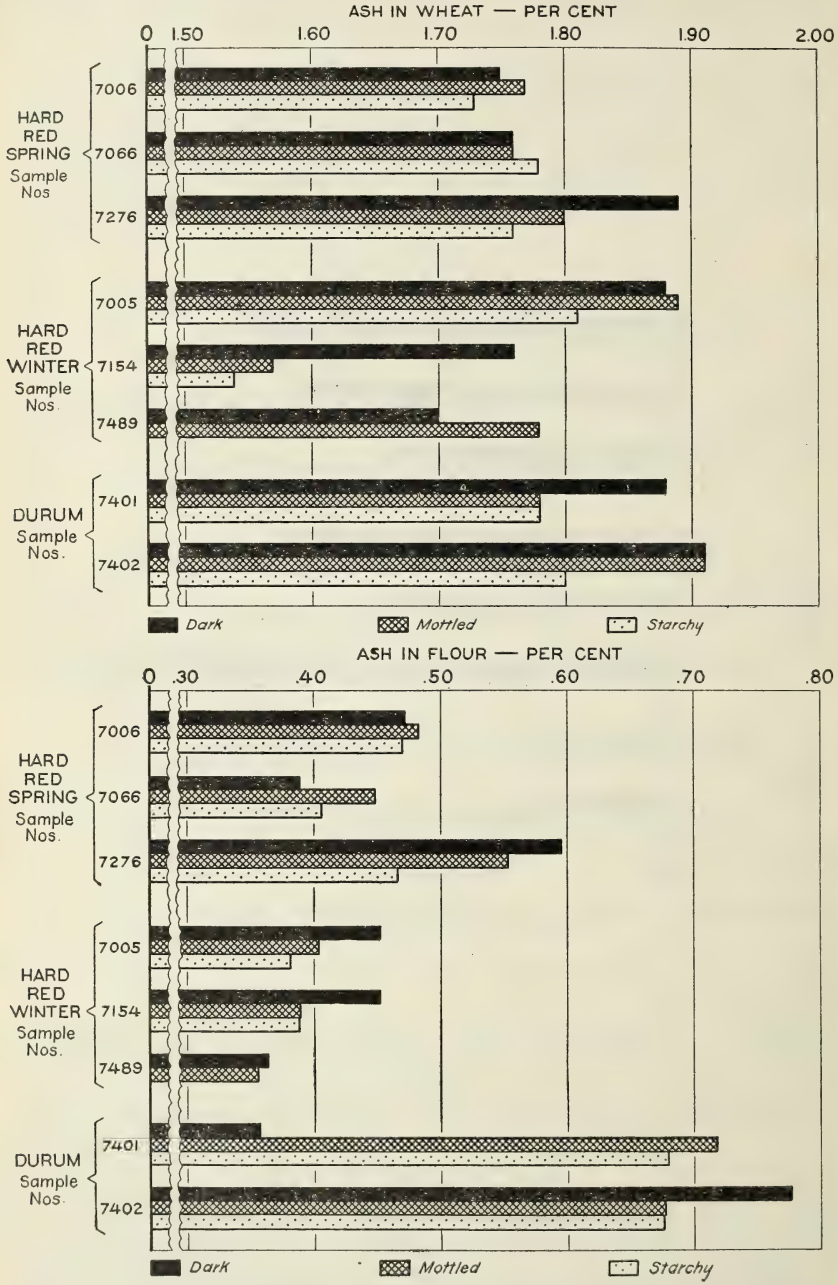

FIG. 4.—Comparison of the ash content of the separations of dark, mottled, and starchy kernels of wheat and of the ash content of the flour milled from each

The fat content was greater in four of the starchy types of kernels than in the more vitreous types.

TABLE 4.—*Chemical composition of the dark, mottled, and starchy kernels as they occur in the same sample of wheat; basis, 13.5 per cent H_2O*

Laboratory No. of sample	Type of kernel texture	Ash	Fat	Fiber	Protein N×5.7	Nitrogen-free extract
	HARD RED SPRING WHEAT SAMPLES					
		Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*
7006	Dark	1.75	1.60	2.87	14.39	65.89
	Mottled	1.77	1.93	2.56	9.86	70.38
	Starchy	1.73	2.04	2.66	8.82	71.24
7066	Dark	1.76	1.99	2.85	11.78	68.13
	Mottled	1.76	2.04	2.60	9.71	70.38
	Starchy	1.78	2.10	2.56	9.86	70.19
7276	Dark	1.89	2.14	2.54	11.63	68.30
	Mottled	1.80	2.01	2.27	9.32	71.10
	Starchy	1.76	2.03	2.34	8.09	72.28
	HARD RED WINTER WHEAT SAMPLES					
7005	Dark	1.88	1.61	2.59	11.78	68.65
	Mottled	1.89	1.67	2.53	10.21	70.21
	Starchy	1.81	1.64	2.49	9.22	71.34
7154	Dark	1.76	1.48	2.49	10.70	70.07
	Mottled	1.57	1.49	2.48	8.18	72.77
	Starchy	1.54	1.46	2.52	7.49	73.49
7489	Dark	1.70	1.63	2.59	13.66	66.92
	Mottled	1.78	1.57	2.52	13.02	67.66
	DURUM WHEAT SAMPLES					
7401	Dark	1.88	2.01	2.53	12.09	68.00
	Mottled	1.78	2.06	2.48	10.01	70.12
	Starchy	1.78	2.15	2.55	8.87	71.14
7402	Dark	1.91	2.02	2.71	11.49	68.37
	Mottled	1.91	1.78	2.60	10.01	70.19
	Starchy	1.80	2.07	2.62	8.93	71.08

CRUDE PROTEIN CONTENT

The crude protein content of the wheats varied from 10.70 per cent to 14.39 per cent for the dark kernel separations, from 8.18 per cent to 13.02 per cent for the mottled kernel separations, and from 7.49 per cent to 9.86 per cent for the starchy kernel separations. Although the variation in the protein content shown for the dark kernels from the different samples is considerable, and although the mottled kernels from one of the samples was higher in protein content than those of the dark kernels from other samples, yet the fact that in every sample the dark kernel separation had the highest protein content and in every sample except one the mottled kernels the next highest protein content is substantial proof of the existence of a close relationship between that factor (protein content) and kernel texture. The variations between samples, on the other hand, instead of disproving this relationship, merely indicate that other factors such as variety, soil, and climatic conditions also have important influences on the protein content of wheat.

Averaging all the samples, a much higher protein content is found in the dark kernels as compared with the mottled and starchy kernels. The mottled kernels had only a slightly higher protein content than

the starchy kernels. The average difference between the dark and mottled kernels was 2.4 per cent, whereas between the mottled and starchy kernels it was only 0.8 per cent. The relationship between

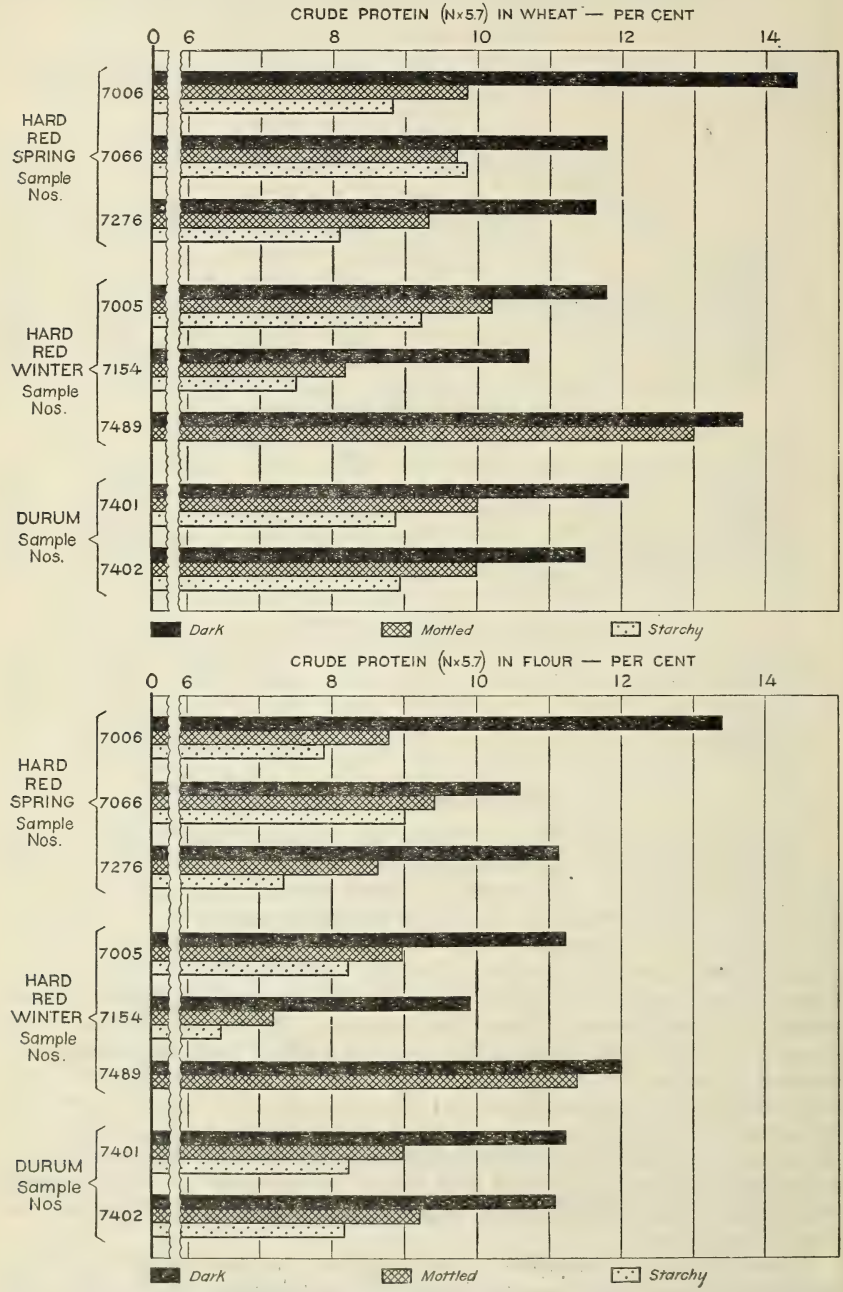

FIG. 5.—Comparison of the protein content of the separations of dark, mottled, and starchy kernels of wheat and of the protein content of the flour milled from each

protein content and the kernel texture of these samples corresponded very closely in kind and extent to that noted in connection with the water absorption of the flour milled from them. The differences between the protein contents of the various separations of each of the samples is shown graphicly in Figure 5.

The nitrogen-free extract—that is, constituents of the wheat such as starches, sugars, gums, etc.—is determined by subtracting the sum of the other analyses from 100. With every sample studied, except No. 7066, this factor increased progressively with the degree of starchiness.

NITROGEN COMPOUNDS OF THE WHEAT

Since it is the gluten-forming compounds of wheat which give flour its bread-making qualities, special attention was paid to the nitrogen compounds in the various types of kernel textures. Tests were made to determine the amounts of albumin, globulin, and gliadin present in the samples under study. The methods employed for determining the gliadin in both the wheat and flour were those recommended by Bailey[1] and Blish.

Tests were first made relative to the nitrogen compounds. A study of the data for this factor, given in Table 5, shows that there was a progressive decrease in the quantity of salt-soluble protein, albumins, and globulins, as the degree of starchiness or softness increased. This fact was the same with all the samples studied. It was found also that the gliadin, or alcohol-soluble protein, decreased in percentage as the percentage of starchiness increased.

Comparing the physical characteristics of the various types of separations with the baking strength of the flour milled from them, it was found that there was a positive correlation between the volume of the loaf and the percentage of salt-soluble and alcohol-soluble proteins, exception to this being noted with the two samples of durum wheats tested.

CHEMICAL COMPOSITION OF FLOURS FROM WHEAT KERNELS OF DIFFERENT TEXTURES

Data obtained regarding the chemical composition of the flours are of more interest than those obtained from a study of the wheats from which they were milled. The data on this phase of the subject are given in Table 5.

The tests made upon the flours included moisture, ash, total protein, gliadin, wet and dry gluten, hydration capacity of the gluten protein, and the acidity of the flour. The results are expressed on a 13.5 per cent moisture basis. As with the wheats, the protein of the flour decreased progressively as the percentage of starchiness increased. This is true likewise of the gliadin. There was a decided decrease in the percentage of wet gluten of flour from the dark kernel separations down to the starchy kernel separations. This factor likewise decreased as the starchiness of the samples increased. What is true of the wet gluten was likewise true of the dry gluten analyses.

Hydration capacity of the gluten decreased as the texture changed from vitreous to starchy in almost every instance.

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[1] Bailey, C. H., and Blish, M. J. concerning the identity of the proteins extracted from wheat flour by the usual solvents. Jour. Biochem., vol. 22, no. 1, p. 345.

With the exception of samples Nos. 7066, and 7006, the ash content changed to a progressively lower percentage, with an increase in the starchiness of the kernel. In most cases the flour from the starchy kernels gave an ash content similar to that obtained from soft wheats.

TABLE 5.—*Percentage of protein, salt-soluble nitrogen, gliadin, wet and dry gluten, hydration capacity of the gluten, ash, and acidity of the flour milled from different types of kernel texture separations; basis, 13.5 per cent H_2O*

Laboratory No. of sample	Type of kernel texture	Protein N×5.7	Salt-soluble nitrogen	Gliadin	Gluten			H_2O absorbed per gram of dry gluten	Ash	Acidity (lactic)
					Wet	Dry	Ratio between wet and dry			
	HARD RED SPRING WHEAT SAMPLES									
		Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
7006	Dark	13.41	1.29	10.37	38.65	14.74	2.62	162.2	0.473	0.215
	Mottled	8.78	1.05	6.55	25.11	10.63	2.36	159.4	.484	.244
	Starchy	7.89							.471	
7066	Dark	10.60	1.19	8.04	30.76	12.03	2.56	155.4	.389	.181
	Mottled	9.42	1.06	6.84	26.32	10.26	2.57	156.8	.449	.214
	Starchy	9.02	1.02	6.61	24.06	9.44	2.55	160.5	.407	.171
7276	Dark	11.14	1.47	7.98	33.67	12.83	2.62	166.1	.596	.267
	Mottled	8.63	1.23	6.38	24.46	9.55	2.56	160.5	.553	.214
	Starchy	7.34	1.11	5.07	19.72	7.73	2.55	164.7	.466	.257
	HARD RED WINTER WHEAT SAMPLES									
7005	Dark	11.24	1.26	8.26	29.99	10.89	2.75	171.6	.452	.184
	Mottled	8.97	1.13	6.84	25.79	9.28	2.77	179.9	.404	.231
	Starchy	8.23	1.00	5.65	20.91	7.63	2.74	169.5	.381	.179
7154	Dark	9.91	1.16	7.58	28.19	10.41	2.71	205.5	.452	.182
	Mottled	7.20	1.00	5.30	19.71	7.13	2.76	180.9	.390	.215
	Starchy	6.46	.78	4.96	15.95	5.95	2.68	167.8	.389	.152
7489	Dark	12.03	1.44	9.29	35.66	10.66	3.35	196.2	.364	.187
	Mottled	11.39	1.39	8.66	32.92	9.82	3.35	191.3	.356	.182
	DURUM WHEAT SAMPLES									
7401	Dark	11.24	1.52	7.64	34.82	11.37	3.06	175.2	.857	.273
	Mottled	8.97	1.31	6.38	29.62	9.82	3.02	172.0	.718	.244
	Starchy	8.23	1.24	5.36	24.22	8.02	3.02	166.6	.680	.245
7402	Dark	11.10	1.44	7.47	34.34	11.14	3.08	173.3	.778	.303
	Mottled	9.22	1.12	6.33	25.25	9.34	2.70	173.2	.677	.245
	Starchy	8.18	1.13	5.53	24.33	8.14	2.99	167.2	.676	.243

The titratable acidity of the flours milled from the starchy separations was usually less than that found in the flours milled from the dark, hard, and vitreous portions. Exceptions to this are noted, however, in samples Nos. 7006, 7066, 7005, and 7154. The flours milled from the mottled kernels bearing these numbers have the highest titratable acidity.

Again, as with the wheat, the percentage of protein, the percentage of gliadin, the percentage of wet and dry gluten, and the water-holding capacity of the gluten decreased in those flours which were milled from wheats of an increasingly starchy character.

The fact that the lower percentages of protein in the flours from the more starchy portions of the hard red spring and hard red winter wheat samples produced a loaf of bread not greatly inferior in size to that obtained from flours milled from the dark or most vitreous

textured kernels is indicative of two things: (1) The quality of the glutenin in the starchy kernels was equal to or better than that in the vitreous kernels; and, (2) the quality was as good as that in the vitreous types of kernels but that the quantity present was not very much below the amount required for producing the best volumes.

COMPARISON OF AVERAGE RESULTS FOR EACH OF THE THREE SEPARATIONS

In Table 6 are given for each of the three separations from all the samples except No. 7489 the average results for the various factors tested. The reason the results of the separations of this sample are not included is because no starchy separations was made, and to include the data of the other two separations would make comparison impossible except between the dark and mottled separations. The data given show the dark separations to average highest in specific gravity, flour yield, milling gain, water absorption of flour, loaf volume, weight of loaf, color and texture of bread, ash in wheat, ash in flour, crude fiber in wheat, and crude protein in both wheat and flour. The mottled separations average highest in test weight per bushel both before and after scouring, weight per 1,000 kernels, and shorts yield. The starchy separations averaged highest in bran yield and fat content of wheat.

TABLE 6.—*Average of results for the three types of separations from all the samples* [1]

	Dark	Mottled	Starchy
Test weight (before scouring)—pounds	62.2	62.7	61.4
Test weight (after scouring)—do	62.7	63.3	62.0
Weight per 1,000 kernels—grams	31.9	33.5	31.8
Specific gravity	1.3996	1.3845	1.3425
Flour yield—per cent	73.0	72.7	71.8
Bran yield—do	14.3	13.5	16.3
Shorts yield—do	14.3	14.5	13.0
Milling gain—do	+1.6	+0.7	+1.1
Water absorption [2]—do	59.3	56.8	53.9
Loaf volume, [2]—cubic centimeters	2047	1960	1947
Weight of loaf [2]—grams	498	494	485
Color of bread—score	93.0	92.9	92.3
Texture of bread—do	90.9	90.4	89.3
Ash in wheat [2]—per cent	1.83	1.78	1.74
Ash in flour [2]—do	.571	.525	.496
Crude fiber in wheat [2]—do	2.65	2.50	2.53
Crude protein in wheat [2]—do	11.98	9.61	8.75
Crude protein in flour [2]—do	11.23	8.74	7.91
Fat in wheat [2]—do	1.84	1.85	1.93

[1] The results from the hard red winter wheat sample No. 7489 are not included here, because no starchy type separation was made; neither are the acidity results for sample No. 7506.
[2] Basis 13.5 per cent moisture content.

SUMMARY

Particular attention is called here to the fact that this experiment and the conclusions here given have chiefly to do with differences in quality among the dark, mottled, and starchy types of kernel texture within the same sample and do not apply to differences between samples. The data given show, however, the occurrence of wide differences between samples of the same class or variety, when grown under different conditions, even to the extent that the highest quality shown for any of the separations from one sample may be lower than the lowest for any of the separations for another sample.

Summarizing the results it was found that of the three types of kernel texture compared, the dark type, for the three classes of wheat studied, was consistently highest in specific gravity, usually highest in flour yield and color of loaf, decidedly superior in water absorption, weight of loaf, and crude protein content, and slightly higher in ash, crude fiber, and acidity. In the hard red spring and hard red winter wheats, but not in the durum, the dark type of kernel was also slightly highest in loaf volume and texture of bread.

The mottled kernel type was superior in test weight per bushel and weight per 1,000 kernels but not to any very marked degree. In most of the other qualities this type was of medium grade.

The starchy type of kernel was slightly superior to the other types in average fat content of wheat and in bran yield for all three classes of wheat tested, and in the durum wheat samples produced the bread of greatest volume and of best texture. In almost all the important milling and bread quality factors the starchy kernels, except of the durum wheat samples, were inferior to the other types.

The dark kernel separations averaged lowest in fat content of wheat. The mottled kernel separations averaged lowest in bran yield, milling gain, and crude fiber in wheat. The starchy kernel separations were lowest in all the other factors listed.

Judged from the standpoint of these averages it would appear that the dark kernels were decidedly superior to the other types of kernels and that the starchy kernels were just as decidedly inferior.

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